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EFFECT OF ZN LEVELS IN COMBINATION WITH MICROBIAL INOCULATION ON SOIL EXCHANGEABLE CA AND MG AND THEIR UPTAKE BY MAIZE

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ABSTRACT

Field experiment was conducted in red soil in order to study the secondary nutrients availability such as calcium and magnesium in red soil by using of Arbuscular Mycorrhizal (AM) fungi and Zinc Solubilizing Bacteria (ZSB) in combination with graded levels of $ZnSO_4$. Treatment consisted of two factors viz., microbial inoculation (M_1: control, M_2: AM fungi, M_3: ZSB and M_4: M_2+M_3) and graded levels of $ZnSO_4$ (S_1: 0, S_2: 12.5, S_3: 25, S_4: 37.5, S_5: 50 Kg ha $^{-1}$ and S_6: 0.5% foliar spray @ 45 and 65 DAS) replicated three times in RBD. The results revealed that the exchangeable Ca and Mg content of soil were positively influenced by the microbial inoculation as well as the graded doses of $ZnSO_4$. These contents were decreased with the advancement of crop growth. Application of AM fungi (M_2) + ZSB (M_4) had highest uptake of Ca and Mg by maize grain and stover. Graded levels of Zn application enhanced the Ca and Mg uptake correspondingly. However, the increase was not significant beyond 25 kg of ZnSO4 ha^{-1}.

KEYWORDS: Maize (Zea mays L.), Arbuscular Mycorrhizal (AM) Fungi, Zinc Solubilizing Bacteria (ZSB), Graded Levels of $ZnSO_4$, Secondary Nutrients, Ca and Mg Uptake

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INTRODUCTION

In India, maize is grown in a wide range of environments, extending from extreme semiarid to sub humid and humid regions. It is grown in about 9.09 M ha (Anonymous, 2014) and utilized for versatile purposes. It is a main source of calories and minerals for most rural populations. Calcium is part of every plant cell. Much of the Ca in plants is part of the cell walls in a compound called calcium pectate. Without adequate Ca, cell walls would collapse and plants would not remain upright. Calcium is not mobile in plants. It does not easily move from old leaves to young leaves. Calcium also has a positive effect on soil properties. This nutrient improves soil structure thereby increasing water penetration, and providing a more favorable soil environment for growth of plant roots and soil microorganisms.

Magnesium is a component of the chlorophyll molecule. Therefore, it is essential for photosynthesis. As might be expected, plants that are deficient in Mg have an overall light green color. In maize, the veins are mainly white when concentrations are inadequate. Red soil had low basic cations viz., Ca and Mg due to low pH, leaching and adsorption on clay complex. Zinc solubilizing bacteria produce gluconic acid (Saravanan *et al.*, 2007), it's solubilize native basic cations such as Ca and Mg in the soils. AM fungi mobilize the solubilized the native basic cations viz., Ca and Mg through the external mycelium (Ameeta and Savitha, 2013). Keeping these in view the

present study in contemplated to study the soil availability of secondary nutrients such as exchangeable Ca and Mg and their uptake by maize.

MATERIALS AND METHODS

Experimental Soil

A field experiment was conducted in red soil during 2014 to study the effect of Arbuscular Mycorrhizal fungi (AMF), Zinc Solubilizing Bacteria (ZSB) and their combinations on red soil at farmer's field, Pullanviduthi, near National Pulses Research Centre (TNAU), Vamban, Pudukkottai district. The soil was Sandy loam, red in colour belonging to *Udic Rhodustalf* (Mudukulam series). The details of soil characteristics are given in Table 1. The initial soil was neutral in reaction, non saline, low status of OC and CEC. The available N was low, P and K were found to be medium. The exchangeable Ca content was 6.12 cmol (p^{+}) kg^{-1} and exchangeable Mg content was 3.56 cmol (p^{+}) kg^{-1}.

Field Experiments

Treatment consisted two factors *viz.*, microbial inoculation (M_1: control, M_2: AM fungi, M_3: ZSB and M_4: M_2+M_3) and graded levels of $ZnSO_4$ (S_1: 0, S_2: 12.5, S_3: 25, S_4: 37.5, S_5: 50 Kg ha^{-1} and S_6:0.5% foliar spray @ 45 and 65 DAS) replicated three times in RBD. Seeds of maize hybrids (NK 6240) were sown on the sides of the ridges by adopting a spacing of 60 x 25 cm along with vermiculite based mycorrhizal inoculum (*Glomus intraradices* TNAU-03-08) 2 g per hill at a depth of 5 cm. Zinc solubilizing bacteria was applied at 2 kg ha^{-1} after mixing it with 25 kg each of sand and farm yard manure. The recommended fertilizer prescription for maize *viz.*, 250:75:75 kg N, P_2O_5 and K_2O kg ha^{-1} was followed. The full dose of P and K were applied basally and N was applied at three splits *viz.*, basal (25%), vegetative (50%) and tasselling (25%) stages. Calculated quantities of $ZnSO_4$ were applied basally as per the treatment schedule. The soil and plant samples were drawn at vegetative (30th), tasselling (60th) and harvest stage (110th) and analysed for Exchangeable Ca & Mg and their content respectively in soil and plant samples. The grain and stover yield were recorded treatment wise and Ca and Mg uptake were computed.

Table 1: Initial Soil Characteristic of the Experiment

S. No.	Particulars	Field Experiment II
1.	Textural class	Sandy loam
2.	Taxonomy	*Udic Rhodustalf*
3.	pH (1:2.5 soil : water)	6.69
4.	EC (dS m^{-1})	0.07
5.	Free $CaCO_3$ (g kg^{-1})	20.1
6.	Organic Carbon (g kg^{-1})	3.53
7.	CEC (c mol (p^{+}) kg^{-1})	12.6
8.	Alkaline $KMnO_4$- N (kg ha^{-1})	210
9.	Olsen- P (kg ha^{-1})	15.4
10.	Neutral N NH_4Oac- K (kg ha^{-1})	208
11.	Exchangeable Ca cmol (p^{+}) kg^{-1}	6.12
12.	Exchangeable Mg cmol (p^{+}) kg^{-1}	3.56

RESULTS AND DISCUSSIONS

The soil exchangeable Ca and Mg content was found to be gradually reduced from the vegetative stage to the harvest stage and this reduction might be due to the crop removal and other transformation in soil (Table 2 & 3). A proportionate increase in soil exchangeable Ca and Mg content was noticed by the application of microbial inoculations combinations with Zn levels. During the crop growth, both the Ca and Mg concentrations were found decreased in all

treatments at the growth stages advanced. Crop uptake, adsorption on clay complex and leaching could be attributed for the decrease in Ca and Mg contents of the soils. Application of AM fungi + ZSB (M_4) recorded highest exchangeable Ca and Mg than the other microbial inoculations (M_2) and (M_3) under both the soils. The reason attributed could be the microbial inoculation would have contributed to the acidification and solubilization of insoluble cations. Among the graded levels of Zn application, S_5 (50 kg of $ZnSO_4$ ha^{-1}) recorded highest exchangeable Ca and Mg in both the soils.

CONCLUSIONS

The Ca and Mg uptake by maize grain was increased to the tune of 46.0% and 43.6% respectively over control (Table 4). Zinc solubilizing bacteria produce gluconic acid, its solubilize native basic cations such as Ca and Mg in the soils. AM fungi mobilize the solubilized the native basic cations viz., Ca and Mg through the external mycelium. Both mechanisms increased the availability of exchangeable Ca and Mg in soil. Hence, it's lead to increase the uptake of Ca and Mg in maize grain and stover.

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APPENDICES

Table 2: Graded Levels of Zn with Arbuscular Mycorrhizal Fungi and Zinc Solubilizing Bacteria on Soil Exchangeable Ca (cmol (p^+) kg^{-1})

Treatments	Vegetative Stage							Tasselling Stage						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
M_1	6.34	7.53	8.67	8.98	9.05	6.36	**7.82**	6.12	7.41	8.43	8.57	8.98	6.13	**7.61**
M_2	6.98	7.78	8.93	9.56	9.67	7.12	**8.34**	6.73	7.49	8.52	9.34	9.41	6.79	**8.05**
M_3	7.01	7.98	8.99	9.68	9.81	7.21	**8.45**	6.87	7.73	8.72	9.31	9.48	7.00	**8.19**
M_4	7.26	8.52	9.34	10.70	10.89	7.43	**9.02**	7.11	8.34	9.12	10.63	10.68	7.27	**8.85**
Mean	**6.90**	**7.95**	**8.98**	**9.73**	**9.86**	**7.03**	**8.41**	**6.71**	**7.74**	**8.70**	**9.46**	**9.63**	**6.80**	**8.17**
		SEd		CD (0.05)					SEd		CD (0.05)			
M		0.09		0.19					0.09		0.19			
S		0.11		0.23					0.11		0.23			
M X S		0.22		NS					0.22		NS			

Treatments	Harvest Stage						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean
M_1	6.03	7.28	8.22	8.31	8.79	6.09	7.45
M_2	6.56	7.38	8.32	9.11	9.23	6.54	7.86
M_3	6.64	7.55	8.48	9.16	9.37	6.81	8.00
M_4	7.03	8.28	9.05	10.41	10.48	7.19	8.74
Mean	**6.57**	**7.62**	**8.52**	**9.25**	**9.47**	**6.66**	**8.01**
		SEd		CD (0.05)			
M		0.09		0.18			
S		0.11		0.23			
M X S		0.22		NS			

Table 3: Graded Levels of Zn with Arbuscular Mycorrhizal Fungi and Zinc Solubilizing Bacteria on Soil Exchangeable Mg (cmol (p$^+$) kg^{-1})

Treatments	Vegetative Stage							Tasselling Stage						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
M_1	3.59	3.83	3.99	4.12	4.14	3.61	**3.88**	3.43	3.69	3.78	3.97	4.01	3.56	**3.74**
M_2	3.65	3.92	4.21	4.45	4.49	3.68	**4.07**	3.61	3.87	4.11	4.39	4.40	3.62	**4.00**
M_3	3.71	3.98	4.28	4.52	4.59	3.79	**4.15**	3.62	3.88	4.11	4.42	4.51	3.67	**4.04**
M_4	3.97	4.34	4.98	5.12	5.19	4.00	**4.60**	3.86	4.21	4.58	5.03	5.10	3.92	**4.45**
Mean	**3.73**	**4.02**	**4.37**	**4.55**	**4.60**	**3.77**	**4.17**	**3.63**	**3.91**	**4.15**	**4.45**	**4.51**	**3.69**	**4.06**
		SEd		CD (0.05)					SEd		CD (0.05)			
M		0.03		0.07					0.03		0.07			
S		0.04		0.08					0.04		0.08			
M X S		0.08		0.16					0.08		0.16			

Treatments	Harvest Stage						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean
M_1	3.21	3.54	3.67	3.82	3.96	3.43	**3.61**
M_2	3.53	3.75	4.01	4.28	4.37	3.56	**3.92**
M_3	3.53	3.74	4.02	4.33	4.45	3.59	**3.94**
M_4	3.76	3.99	4.41	4.87	5	3.78	**4.30**
Mean	**3.51**	**3.76**	**4.03**	**4.33**	**4.45**	**3.59**	**3.94**
		SEd		CD (0.05)			
M		0.03		0.06			
S		0.04		0.08			
M X S		0.08		0.16			

Table 4: Graded Levels of Zn with Arbuscular Mycorrhizal Fungi and Zinc Solubilizing Bacteria on Calcium uptake (kg ha^{-1}) by Grain and Stover

Treatments	Grain uptake							Stover uptake						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean	S_1	S_2	S_3	S_4	S_5	S_6	Mean
M_1	1.15	1.60	1.85	2.20	2.25	1.45	**1.75**	17.8	26.1	30.5	32.2	31.7	25.7	**27.3**
M_2	1.40	1.60	1.95	2.25	2.30	1.50	**1.83**	26.3	31.3	33.8	37.5	36.1	28.5	**32.2**
M_3	1.50	1.70	2.15	2.30	2.35	1.60	**1.93**	28.3	31.7	36.0	40.0	38.3	30.2	**34.1**
M_4	1.70	1.95	2.20	2.55	2.55	1.80	**2.13**	30.6	36.4	40.2	44.3	43.4	34.9	**38.3**
Mean	**1.44**	**1.71**	**2.04**	**2.33**	**2.36**	**1.59**	**1.91**	**25.7**	**31.4**	**35.1**	**38.5**	**37.4**	**29.8**	**33.0**
		SEd		CD (0.05)					SEd		CD (0.05)			
M		0.07		0.14					0.98		2.0			
S		0.08		0.17					1.20		2.5			
M X S		0.16		NS					2.40		NS			